Effect of Mechanical Surface Treatment on the Tensile Bond Strength of Repaired Acrylic Denture Base Resin Cured by Two Different Techniques

Israa M. Hummudi, M.Sc.*

المستخلص

الهدف: مقارنة معالجة السطوح المرممة لقواعد الطقم المكسور بطريقة ميكانيكية بواسطة جزيئات أوكسيد الألمنيوم وعمل خندق بمواصفات معينة وتقييم قوة الشد التوتري بعد المعالجة باستعمال الاكريلك الحراري والمايكروويف.

المنهجيّة: تمّ تحضير ٨٠ عيّنة من مادّة الاكريلك الحار ثم قسّمَت العيّنات إلى مجموعتين رئيستين (٤٠ عيّنة) تمّت معالجتها بواسطة الطبخ بالحمام المائي و(٤٠عيّنة) تمّت معالجتها بواسطة جهاز المايكروويف ثم قسّمَت كل مجموعة إلى أربع مجاميع حَسَب السطوح المراد معالجتها إلى ١٠ نماذج في كل مجموعة؛مجموعة حُفِظَت بدون كسر،مجموعة ب كُسِرَت وبدون معالجة، مجموعة ج، د عولجت بواسطة جزيئات الألمنيوم وعمل خندق بطول وسمك معينين.تمّ اختبار قوة الشدّ التوتري لجميع النماذج بواسطة جهاز الفحص الخاص.

النتائج: أظهرت النتائج أنّ النماذج المطبوخة بواسطة الحمام المائي لها قوة شد أعلى من النماذج المطبوخة بواسطة المايكروويف وأنّ النماذج المعاملة بواسطة الخندق وجزيئات أوكسيد الألمنيوم أظهرت قوة شد أعلى من النماذج غير المعالجة.

التوصيات: يمكن الاستنتاج بأن معالجة السطح المرمّم بطريقة ميكانيكية يُعَدّمقياساً مهماً في عملية تقويم الأطقم الاكريلية المرممة.

Abstract:

Objective: To evaluate and compare the effect of mechanical surface treatment (groove, aluminum oxide particles) with 45 degree bevel type of joint on tensile bond strength of acrylic specimens repaired by two curing methods (microwave and water both).

Methodology: Eighty specimens (80) were prepared from pink heat cure acrylic resin. They were divided into two main groups (40 specimen repaired by microwave energy and 40 specimens repaired by water bath method).Each group can be divided into four subgroups of ten according to the surface treatment. The control group A was left intact, group B received no surface treatment, group C and D received surface treatment by (groove, 50 m aluminum oxide particles). Specimens were tasted by using an instron universal testing machine until fracture occurs.

Result: The results indicate that nurses have adequate knowledge toward general information on infection, infection control strategy, causes, prevention, sterilization and disinfection, and healthy conditions in operating room environment. Regarding practices, the results indicated inadequate practices concerning the standard precaution during wearing operation clothing, patient's preparation, and hand washing practices. While, their practices concerning tools and equipment preparations were adequate. There is a significant relationship between nurses' knowledge and practices and their educational level and years of experience.

Recommendation: It can be concluded that mechanical surface treatment prior to denture base repair resulted in a significant improvement the tensile bond strength of denture base resin.

Keywords: Mechanical Surface Treatment; Tensile Bond; Repaired Acrylic Dentures

Introduction

Removable dentures made of acrylic resin are subjected to fracture if dropped or stressed beyond their fracture strength. Fabrication of new denture is an expensive and time consuming procedure and for this reason the decision to repair a denture is a common one [1]. Heat polymerized, visible light polymerized and microwave polymerized acrylic resin have been used to repair fractured denture [2,3].

Although various materials have been proposed for repairing fracture denture bases, the use of heat polymerizing resin is the most popular. It should be mentioned that repairing with auto polymerized is much weaker than the originally used heat polymerized denture resin [4]. Attempts have been made to improve the mechanical properties of repaired sites by changing either the joint surface contour or by using surface treatment [5,6]. Surface preparation of the sites to be joined is of paramount importance in ensuring along surface life. Chemical or mechanical treatments change the morphology or surface chemistry of the acrylic resin base materials to promote better adhesion [1].

***Assistant Instructor, College of Health and Medical Technologies, Foundation of Technical Education**

In the present study tensile strength of repaired acrylic specimens had been evaluated using two mechanical surface treatments joining repair surfaces (groove, aluminum oxide particles) in addition to evaluate the effect of the curing methods [2].

Material and Methods

Specimens grouping:

Eighty specimens (80) were prepared from pink heat cure acrylic resin and were divided according to the methods of curing in to group (one) forty (40) specimens for water bath curing and group (two) (forty (40)) specimen for microwave curing.

Each group can be divided into four sub group according to the surface treatment as follows:-

Group A: unrepaired acrylic specimen made from heat cure acrylic resin (control group).
Group B: untreated acrylic specimens.
Group C: the repaired joint of the specimens treated with groove.
Group D: The repaired joint of the specimens treated with the aluminum oxide particles.
Each group contains ten specimen.

Figure 1. Metal pattern for tensile strength test

General preparation of the acrylic specimen:

The metal pattern was constructed with a dimension of (65 mm X 12.5mm X 2.5 mm) length, width, thickness to be used in tensile bond strength test according to the ADA specification no. 15 (1980). Figure 1.

Mold preparation:

The conventional flasking technique for complete dentures was followed in the mold preparation. Two metal patterns were coated with a separating medium and allowed to dry before investing them in the lower half of the flask which contained stone mixed according to the manufacturer instruction (100 gm/31 ml); (p/w), and allowed to set. The metal patterns were inserted to one half of its depth.

The stone and metal patterns were coated with separating medium and allowed to dry and then the upper half of the flask was assembled and filled with stone mixtures and allowed to be hardened for 60 minutes before the flask was opened.

After removal of the metal patterns carefully with help of the wax knife, the two halves of the mold were coated with separating medium to be ready for packing with acrylic dough.

Proportioning and mixing of acrylic

Pink heat cure acrylic powder with the liquid was mixed according to manufactures instructions (2.25 gm/1 Ml). (p/I), the liquid was placed in clean and dry mixing vessel followed by slow addition of powder. The mixture was then stirred with wax knife and left to stand in a closed container at room temperature until reaching the dough stage. For packing into gypsum mould when it was separated cleanly from the walls of the mixing jar. The acrylic resin dough was used when no more stuck to the vessel walls. The resin was removed from its mixing container and rolled, then packed into the mould which had been treated with separating medium. The two halves of the flask were closed together and placed under the hydraulic press, and then the pressure was slowly applied to allow even flow of the dough throughout the mould space. The pressure (20 bar) was then released [7]. The flask was opened and the over flowed material (flash) surrounding the mould space was removed with wax knife. A second trial closure was performed; the stone surface was again coated with the separating medium, allowed to dry. The two halves of the flask were finally closed until an intimate contact had been established and left under the press (150 psi) for (5) minutes before clamping was done then the flask was placed in a flask clamp maintaining undisturbed pressure during processing [8].

Curing was carried out by placing the clamped flask in a thermostatically controlled water bath and processed by heating at 74ºC for 1.5 hour and the temperature was then increased to the boiling point for half an hour [9]. After completing the curing, the flask was allowed to cool slowly at room temperature for 30 minutes, followed by a complete cooling of the flask with tap water for 15 minutes before deflasking. The acrylic patterns were then removed from the stone mould. All flashes of acrylic were removed with an acrylic bur. To get a smooth surface, the stone bur should be used followed by (120) grain size sand paper to remove any remaining small scratches with continuous water cooling.

While, polishing was accomplished by using bristle brush and pumice with lathe polishing machine, a glossy surface was obtained with wool brush and polishing soap on dental lathe using low speed (1500 rpm) and the specimens were continuously cooled with water to avoid overheating, which may lead to distortion of the specimens. Finally, the specimens were conditioned for two weeks in distilled water at 37ºC.

Preparation of the repaired acrylic specimens:

The stone mold which had been used for processing the acrylic samples was used then as an index for these specimens in the repair procedure. The samples and indices were numbered on corresponding ends to allow realignment in the original position.

Preparation of the repaired acrylic specimens without surface treatment

Fracturing and joint preparation:

The specimens were repaired with 45-degree bevel joint by using metal holding device had a central recess. The dimension of the central recess of the holding device for preparation tensile strength was (31mm X 12.5 mm width from posterior end of the recess and 5mm width from the open end of the recess) X 2.5mm thickness).

The acrylic specimen was placed in the central groove and cut with a fissure bur near the bevel end. The other end was put aside during the preparation of the part inside the central recess. The cut end was prepared with acrylic bur and finished with a (120) grain size sand paper for (1) minute with fixed speed and water cooling, then polished with pumice for 1/2 minute. Figure (2).

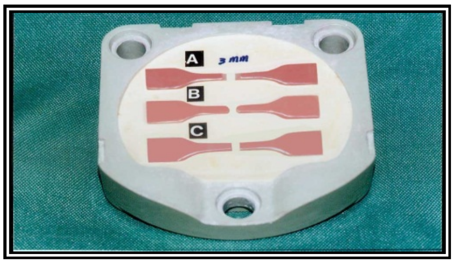

Figure 2. Fractured acrylic specimens placed in the stone mold with 3mm gap for tensile strength

- Repair curing methods:

1- Repair by conventional (water bath) curing method.
2- Repair by microwave curing method.

Mixing and packing

The two parts of sample to be repaired were realigned in it is repair index after painting it with separating media.

The manufacturers instructions was followed in proportion and mixing of the polymer and monomer, the polymer/monomer ratio used was 2.25 gm/1ml. the mixture was packed into the joint after the dough stage was reached by wax knife, with slight excess of material to account for polymerization shrinkage and finishing [(8).]

The two halves of the flask were finally closed together and pressed in a hydraulic press under (1500 psi) for 5 minutes before clamping was done and then transferred to the water bath while for the microwave acrylic resin fiber reinforced plastic (FRP) flask was used the bolts were placed and then the bolts were tightened by using the wrench and then transferred to the microwave oven for a curing (Fig. 3).

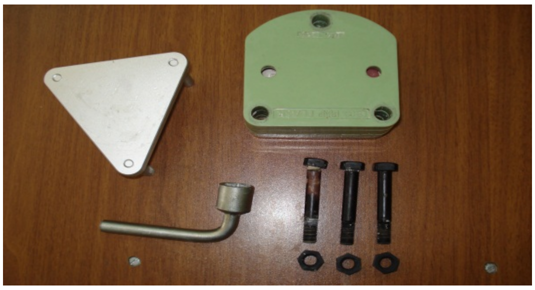

Figure 3. Auxiliaries of FRP Flask

Curing:

Curing was carried out by placing the clamped flask in a water bath and processed by heating at 70ºC for 7 hours and then at 100C for 3 hours (long curing cycle) [3].

While for microwave curing method instruction of the manufactures for the curing cycles were followed. The microwave used in this study with 1000 watts, maximum output representing 10% power level of control settings. The power level was set at 50% to get 450 watt output for 3 minutes (Fig. 4).

Following completion of curing (either by water bath or microwave oven) the flasks were allowed to cool slowly at room temperature for 30 minutes then immersed in water for 15 minutes after that the repaired acrylic specimens were removed from the stone mold then finished and polished.

Figure 4. Microware oven used in the study

Conditioning of the specimens:

According to the ADA specification No.12 (1999), all the repaired specimen were stored in distilled water at 37ºC for 48 hours before testing.

Preparation of the repaired acrylic specimen with different surface treatment

The same procedure in the preparation of repaired specimen without treatment with the exception that before mixing and packing steps, the following additional procedures were done according to the group of specimens they were:

A - Aluminum oxide roughening (micro blasting)

The repaired joint was roughening by air borne particles abrasion with 50 m aluminum oxide particles at pressure of 0.5 Mpa for 5 seconds [10].

.

B- Groove:

The restoration groove was prepared by using medium size fissure bur at 1500 rpm speed for 3 seconds to produce horizontal groove (0.5 mm length 0.5 depth) for each side of repair joint specimen [11].

Mechanical test

Tensile bond strength:

From dumbell metal patter (80) specimen were prepared with dimensions of 65mm X 12.5 X 2.5 ± 0.03 mm) length, width, thickness respectively**.**

Test equipment and procedure:

The tensile strength was tested using instron testing machine with grips suitable for holding the test specimens at across-head speed of 0.5 mm / min and 20mm/min.chart speed. The load cell was measured by a tensile load cell with a maximum capacity 200kg specimens were loaded until fracture, and the load of the fracture was recorded from instron graph readies in kilograms (kg) which were converted into Newton (N). The values of tensile strength were calculated for each test group according to the following formula [12]

$$T.S. = \frac{F}{A}$$

T.S = tensile strength (N/mm^2)
F= force at failure (N)
A= Area of cross section at failure (mm)

Statistical analysis:

1- Descriptive statistics:
- (A) – Statistical table.
- (B) – Arithmetic mean.
- (C) – Standard Deviation.
- (D) – Minimum and maximum readings
- (E) - Bar charts

2- Inferential statistics:
Analysis of variance (ANOVA) test (F-test)
Least significant difference (LSD) test (F-test)
Paired samples student T-test

Results:

Descriptive and inferential statistics of tensile strength of control group and repaired acrylic specimens that were cured by the conventional water bath and microwave curing methods as influenced by different surface treatments (untreated, groove, aluminum oxide particles) were measured and then compare between the results of them as follows:

In water bath curing method the tensile strength values in Table (1) and figure (5) was highest mean in control group specimens and specimens treated with aluminum oxide particles. While, lowest mean values was obtained in untreated specimens group.

One way ANOVA with LSD observed a highly significant differences ($P<0.01$) between control group specimens, untreated, and surface treatment group specimens (groove,Al_2O_3) when compared between each other shown as Table (2).

Table 1. Descriptive statistics for tensile strength according to the surface treatments specimens cured by water bath

Tensile bond strength (N/mm2)

	N	Mean	Std. Deviation	Std. Error	Range		ANOVA test (P-value)	Sig.
					Minimum	Maximum		
Control	10	72.6080	4.4990	1.4227	67.22	80.19		
Untreated	10	39.8790	4.5784	1.4478	35.19	48.05		
Groove	10	49.4550	6.3722	2.0151	39.60	59.40	.000	HS
AL2O3	10	72.7180	3.6937	1.1680	69.10	78.85		
Total	40							

ANOVA= Analysis of variance; n= Number; P-value= Level of probability at $p<0.05$; Sig.= Significance; Std. Deviation= Standard deviation

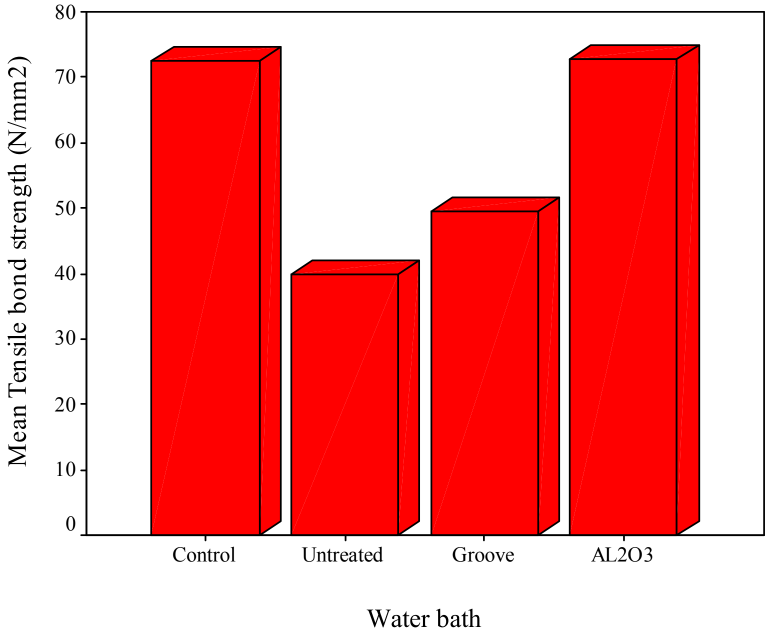

Figure 5. Descriptive statistics for tensile strength according to the control and Specimens with different surface treatment cured by water bath

Table 2. The results of multiple comparison test (LSD) of tensile strength between control and tested specimens group

Dependent Variable: Tensile bond strength (N/mm2)
LSD

Water bath		LSD test P-value	Sig.
Control	Untreated	.000	HS
	Groove	.000	HS
	AL2O3	.960	HS
Untreated	Groove	.000	HS
	AL2O3	.000	HS
Groove	AL2O3	.000	HS

LSD= Least significant difference; P-value= Level of probability at p<0.05; Sig.= Significance

In microwave curing method the tensile strength values in Table (3) and Figure (6) was highest mean in control group specimens and specimens treated with aluminum oxide particles while lowest mean values was obtained in untreated specimens group.

One way ANOVA with LSD observed a highly significant differences (P<0.01) between control group specimens, untreated, and surface treatment group specimens (groove, Al2O3) when compared between each other shown as Table (4).

Table 3. Descriptive statistics for tensile strength according to the surface treatments specimens cured by microwave

Tensile bond strength (N/mm2)

	N	Mean	Std. Deviation	Std. Error	Range Minimum	Range Maximum	ANOVA test (P-value)	Sig.
Control	10	72.6080	4.4990	1.4227	67.22	80.19		
Untreated	10	35.1190	6.1972	1.9597	30.05	45.80		
Groove	10	41.7000	5.9391	1.8781	32.20	49.85	.000	HS
AL2O3	10	68.7900	4.2191	1.3342	62.80	75.20		
Total	40							

ANOVA= Analysis of variance; n= Number; P-value= Level of probability at p<0.05; Sig.= Significance; Std. Deviation= Standard deviation

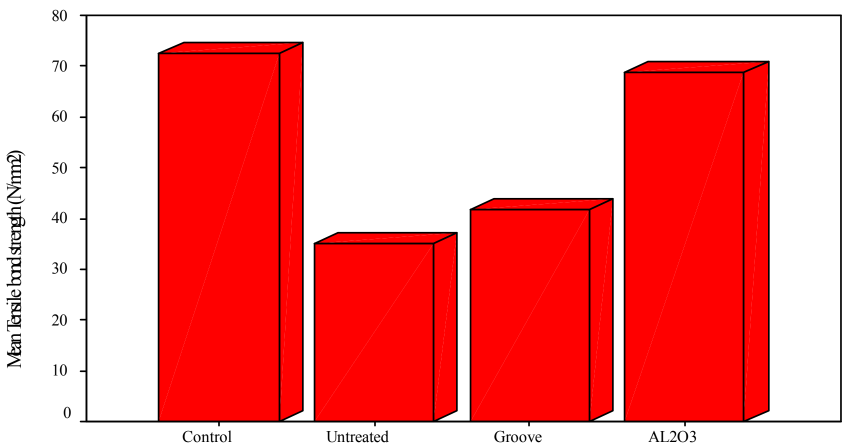

Figure 6. Descriptive statistics for tensile strength according to the control and Specimens with different surface treatment cured by microwave

Table 4. The results of multiple comparison test (LSD) of tensile strength between control and tested specimens group for microwave curing

Microwave		LSD test P-value	Sig.
Control	Untreated	.000	HS
	Groove	.000	HS
	AL2O3	.115	NS
Untreated	Groove	.008	HS
	AL2O3	.000	HS
Groove	AL2O3	.000	HS

AL2O3= Aluminum Oxide; HS= Highly significant; LSD= Least significant difference; P-value= Level of probability at p<0.05; S=Significant; Sig.= Significance

Effect of curing techniques

Paired samples student (t-test) observed a significant differences at (P<0.05) between two curing techniques in favor of water bath over microwave curing techniques in all surface treatments groups shown as table (5) and figure (7).

Table 5. T-test between water bath and microwave curing techniques

Curing technique		t- test (P- value)	Sig.
Untreated	water path Microwave	.040	S
Groove	water path Microwave	.011	S
Al2 O3	water path Microwave	.040	S

AL2O3= Aluminum Oxide; P-value= Level of probability at p<0.05; Sig.= Significance

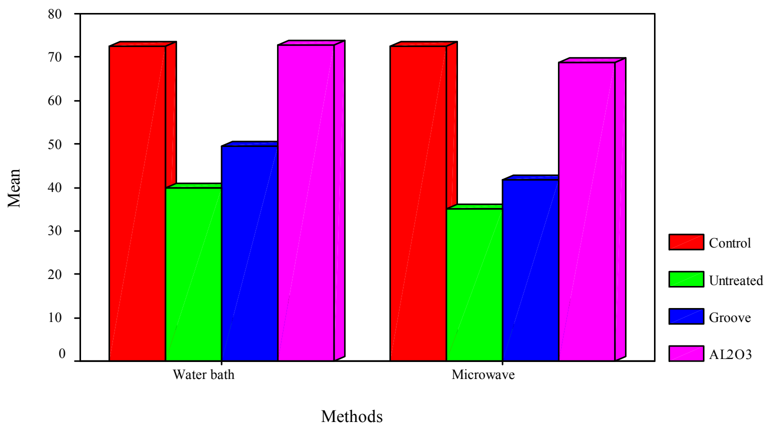

Figure 7. Comparison between two curing techniques

Discussion

The results of this study showed that the tensile strength values of repaired acrylic specimens have been influenced by different surface treatments cured by microwave cured acrylic resin which was significantly lower than those cured by conventional water bath cured acrylic resin as shown in table (5) this may be due to alteration in the composition of monomer or polymer and degree of polymerization. Further that the nature of microwave cured acrylic resin resulted in less interpenetration of the repaired surface, and repaired resin polymer networks, moreover , the un polymerized repair material in contact with the repair surface was significantly less time with the microwave procedure then that with the conventional water bath one, there may be less swelling which lead to less interpenetrating and thus decreasing the bond strength both microwave and water both cured resins are cross link but the exact degree is unknown[13,14]. Denture base resins first introduced tend to craze and fracture easily. Cross linking helped to solve the problem of crazing, but it made the bonding to plastic more difficult [15].The microwave cured resin may highly cross-linked so less unlinked polymer, which could have left fewer functional group available for bonding for that microwave cured resin exhibited low tensile strength values and adhesive bond failure mostly[11].

In the present study roughening of the acrylic specimen by air blasting with Aluminum oxide particles caused significant increase in the bond strength. This may be due to fact that for bonding where some mechanical inter locking might have occurred across the interface. It is also second likely that the increased magnitude of bond strength could have been derived from an enhanced surface reactivity as a result of the removal of a saturated surface layer by grinding and the exposure of the sub surface layer of a higher free surface energy available for bonding [10,11,16,17]. Minami reported a significant increase in bond strength between the denture base resin and an auto polymerizing resin that the rough surface increases the friction between the denture base and repair material, requiring more debonding force at the inter face. Also the mechanical retention in the form of a grind or groove placed in the acrylic surface increased the bond strength. This due to better bond strength was attributed to greater surface area and better penetration between repair mattered and resin base irregularities [18-19].

Conclusion

It can be concluded that mechanical surface treatment prior to denture base repair resulted in a significant improvement the tensile bond strength of denture base resin.

Recommendations

1-Effect of different surface treatment on the transverse strength of repaired acrylic resin.

2-Effect of aluminum oxide particles on the tensile strength of repaired acrylic resin cured by cold cure, visible light cure.

References

1- Sarac SY, Sarac D, Kulunk T, Kulunk S. The effect of chemical surface treatment of the different denture-base resin on shear bond strength of denture repair**.** *J of Prosthet Dent.* 2005;94(3): 259-266.

2- Dar Odeh NS, Harrison A, Abu-Hammad D. An evaluation of self-cured and visible light-cured denture base materials when used as a denture-base repair material. *J. of Oral Rehabil.* 1997; 24(10): 755-760.

3- Polyzois GL, Handly RW, Stafford GD. Repair strength of denture base using various methods. *J. of Prosthet. Dent***.** 1995; Jun. 3(4): 183-6.

4 -Polyzois GL, Tarantili PA, Frangou M.J., Andero Poulos AG. Fracture force, deflection at fracture, and toughness of repaired denture resin subjected to microwave polymerization. *J of Prosthet Dent*. 2001; 86(6): 613-19.

5- Ward JE, Moon PC, Levine RA, Behrendt CL. Effect of repair surface design, repair material and processing method on the transverse strength of repaired acrylic denture resin**.** *J of Prosthet Dent*. 1992; 67(6): 815-20.

6- Shimizu H, Ikuyama T, Hayakawa E, Tsue F, Takaahashi Y. Effect of surface preparation using ethyl acetate on repair strength of denture-base resin**.** *Acta Odontol Scand* 2006; 64(3): 159-63.

7- Abdul-Karim JF. *Evaluation of some mechanical properties of acrylic denture base resin relined with different denture reline materials***.** Unpublished master thesis, College of Dentistry, University of Baghdad; 2002.

8- Rached RN, Powers JM, Del Bel Cury AA. Repair strength of autopolymerizing, microwave and conventional heat polymerized acrylic resins. *J. of Prosthet Dent* 2004; 92(1): 79-82.

9- American Dentists Association (ADA): American National Standards Institute/American Dental Association Specification No.12 for Denture-base Polymer. Chicago: Councilon. *Dental Material and Devices*, 1999.

10- Memariana M, Shayestehma J db M. The effect of chemical and mechanical treatment of denture-base resin surface on the shear bond strength of dentures *Rev. Cl. Resq Odontol*. 2009;5(1): 11-17.

11- Amin WM. Improving bonding of acrylic teeth to self-polymerizing denture-base resins. *Saudi Dental Journal*, 2002; 14(1).

12- Craig RG, Powers JM. *Restorative Dental Materials*. 11^{th} ed. St. Louis: Mosby; 2002.

13- Shneider RL, Curitis ER, Clan Cy JM. Tensile bond strength of acrylic resin denture teeth to a microwave or heat-processed denture-base. *J. of Prosthet Dent*. 2002;88(2): 145-150.

14- Takahashi Y, Chai J, Takahashi T, Habu TJ. Effect of surface treatment on the bond strength between denture-base and repaired acrylic resin. *J of Prosthet Dent*. 2000; 13(1): 59-65.

15- Ellis B, Faraj SA. The structure and surface topographies of acrylic denture-base materials**.** *J of Prosthet Dent.* 1980; 8(12): 102-108.

16- Minami H, Suzuki S, Minesaki Y, Kura Shige H, and Tanaka T. Anvitro evaluation of the influence of repairing condition of denture-base resin on the bonding of auto polymerizing resins. *J of Prosthe Dent.* 2004; 91: 164-170.

17- Jagger DC, Jagger RG, Allen SM, Harrison A. An investigation into the Transverse and Impact Strength of Denture-base Acrylic Resin. *J. of Oral Rehabil.* 2002; 29(3): 263-67.

Cunningham J L. Shear bond strength to heat-cured and light-cured denture-base resin. *J of Oral Rehabil*. 2000; 27: 316-312.

18- Vallittu PK, Lassila VP, Lappalinen R. Evaluation of damage to removable denture in two cities in Finland. *Acta Odontal Scand*. 1993; Dec. 51(6): 363-9.